

8. Viterbi

Viterbi [algorithm]

Claim Term	CMU's Constructions	Marvell's Construction
<p>Viterbi [algorithm]</p> <p>'839 Patent Claims 1, 4, 11, 16, 19, 23</p>	<p>an iterative algorithm that uses a trellis to determine the best sequence of hidden states (in this case, written symbols) based on observed events (in this case, observed readings that represent the written symbols), where the determined sequence is indicated by the best path through the trellis.</p> <p>CMU Brf. at 35-36 (CMU Reply at 10 n. 13)</p>	<p>an algorithm that uses a trellis to perform sequence detection by</p> <ul style="list-style-type: none"> calculating branch metrics for each branch of the trellis, comparing the accumulated branch metrics for extensions of retained paths leading to each node of the trellis at a given time, and for each node, retaining only the path having the best accumulated metric. <p>Marvell Brf. at 36-40</p>

- The Dispute:
 - ▶ Does “Viterbi [algorithm]” refer to a well-known signal-processing algorithm (Marvell) or does the term broadly cover any algorithm for determining the best path through a trellis (CMU)?

Claim Language

- “Viterbi” in ’839 Patent claim preambles

1. A method of determining branch metric values for branches of a trellis for a **Viterbi**-like detector, comprising: selecting a branch metric function for each of the branches at a certain time index; and applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric function was selected, wherein each sample corresponds to a different sampling time instant.

shows the perfor-
FIG. 9 is similar
increased. This
original signal and
PR4 shaping filter
(C2) still output
value of exploit
FIG. 10 show
EPR4 detectors
higher than in the
of 4.4a. This is
right by 2 dB in
the required SCA
LPR4(Loc) and it
is about 1 dB.
metric is more re
in FIG. 11 where
of 10^{-3} is plotted
detectors. From
with an SCAW
operates at a line
the EPR4(C2) de
achieving a gain
Symbol separati
spends to a very
very low number
the detectors at
percolation of m
linear amplitude
23 show the per
detectors at this
comperform the
high in all cases
of 2.5a, nonlinear
percolation of its
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Quantitatively, it
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Qualitatively, the
samples, the gra
and its correlation
While the pre
junction with prefer
embodiments thereof,
modifications and variations
will be apparent to those of
ordinary skill in the art. For example,
the present invention may be
used to detect a sequence that
exploits the correlation
between adjacent signal samples
for adaptively detecting a
sequence of symbols through a
communications channel.
The foregoing description and the
following claims are intended to
cover all such modifications and
variations.

What is claimed is:
1. A method of determining branch metric values for branches of a trellis for a Viterbi-like detector, comprising:
selecting a branch metric function for each of the branches at a certain time index; and
applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch

metric value is calculated by a trellis branch dependent covariance of said signal samples;
calculating a third value representing a quadratic of a subset of said signal samples less a plurality of channel target values normalized by a trellis branch dependent covariance of said subset of signal samples;
calculating the branch weight from said first, second, and third values; and

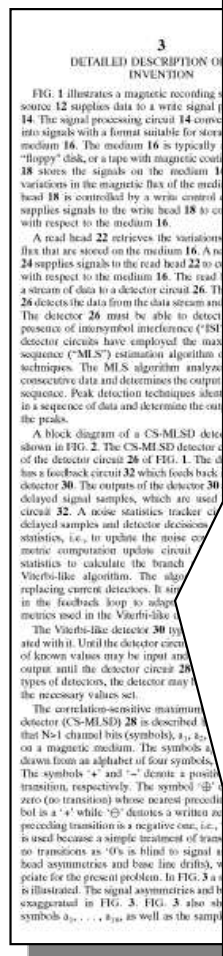
See '839 Patent Claims 1, 4, 11, 16, 19, 23

Specification

• “Viterbi” Algorithm and Detectors

A block diagram of a CS-MLSD detector circuit 28 is shown in FIG. 2. The CS-MLSD detector circuit 28 is a part of the detector circuit 26 of FIG. 1. The detector circuit 28 has a feedback circuit 32 which feeds back into a **Viterbi-like detector 30**. The outputs of the detector 30 are decisions and delayed signal samples, which are used by the feedback circuit 32. A noise statistics tracker circuit 34 uses the delayed samples and detector decisions to update the noise statistics, i.e., to update the noise covariance matrices. A metric computation update circuit 36 uses the updated statistics to calculate the branch metrics needed in the **Viterbi-like algorithm**. The algorithm does not require replacing current detectors. It simply adds two new blocks in the feedback loop to adaptively estimate the branch metrics used in the **Viterbi-like detector 30**.

The **Viterbi-like detector 30** typically has a delay associated with it. Until the detector circuit 28 is initialized, signals of known values may be input and delayed signals are not output until the detector circuit 28 is initialized. In other types of detectors, the detector may be initialized by having the necessary values set.



Prosecution History

- Fitzpatrick Patent
 - ▶ Cited during prosecution

The Examiner rejected claims 1-10 and 27-29 as being anticipated by U.S. Patent No. 5,689,532 to Fitzpatrick. Applicants have herein cancelled claim 29. The Examiner

6/12/00 Amdt. at 8, '839 Patent File History
(Marvell Exh. 22)

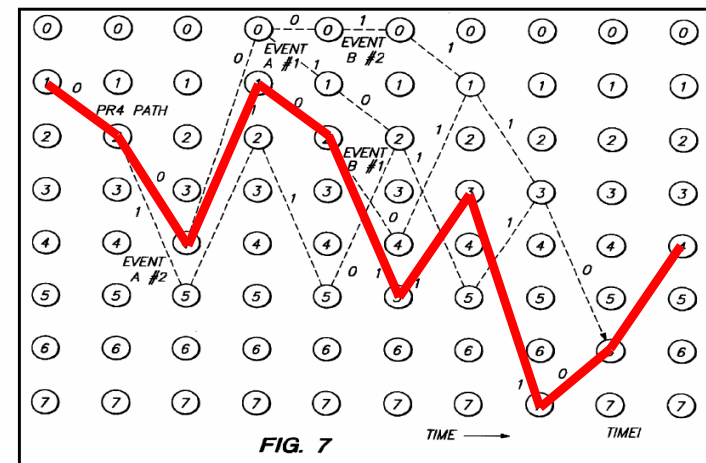
- ▶ Explicitly describes the Viterbi Algorithm

United States Patent [19]
Fitzpatrick

[11] **Patent Number:** **5,689,532**
[45] **Date of Patent:** ***Nov. 18, 1997**

distributed Gaussian noise with zero mean. The Viterbi algorithm is an iterative process of keeping track of the path with the smallest accumulated metric leading to each state in the trellis. The metrics of all of the paths leading into a particular state are calculated and compared. Then, the path with the smallest metric is selected as the survivor path. In this manner all paths which can not be part of the minimum metric path through the trellis are systematically eliminated.

U.S. Patent No. 5,689,532 7:64-8:4
(Marvell Exh. 37)



Prosecution History

- Marvell Includes all Viterbi Algorithm steps

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(Marvell Exh. 37)

- See *also* Proakis Decl. at ¶¶ 48-49.

Marvell's Construction

an algorithm that uses a trellis to perform sequence detection by

- calculating branch metrics for each branch of the trellis,
- comparing the accumulated branch metrics for extensions of retained paths leading to each node of the trellis at a given time,
- and for each node, retaining only the path having the best accumulated metric.

Marvell Brf. at 36-40

Prof. McLaughlin's Three-Step Viterbi Algorithm

- Prof. McLaughlin at Tutorial:
“accumulating values ... by
doing a very simple, what’s called
[add] compare/select.

“**Add**” means I’m going to add what was along
this branch with what it is I had before.

“**Compare**” means I’m going to pick the one
that’s smallest, and I’m going to compare it,

which one is smallest, and **selecting** so that
I, in a very efficient way, instead of
exhaustively searching all the paths in the
disk, I have a systematic way of standing
here and moving stage, by stage, and
stage, and at the end, what I picked is
the one that has the overall smallest cost.”

Marvell's Construction

an algorithm that uses a
trellis to perform sequence
detection by
calculating branch metrics
for each branch of the trellis,
comparing the
accumulated branch metrics
for extensions of retained
paths leading to each node
of the trellis at a given time,
and for each node,
retaining only the path
having the best
accumulated metric.

Marvell Brf. at 36-40

Tutorial 4/7/10 Tr. 74:3-13

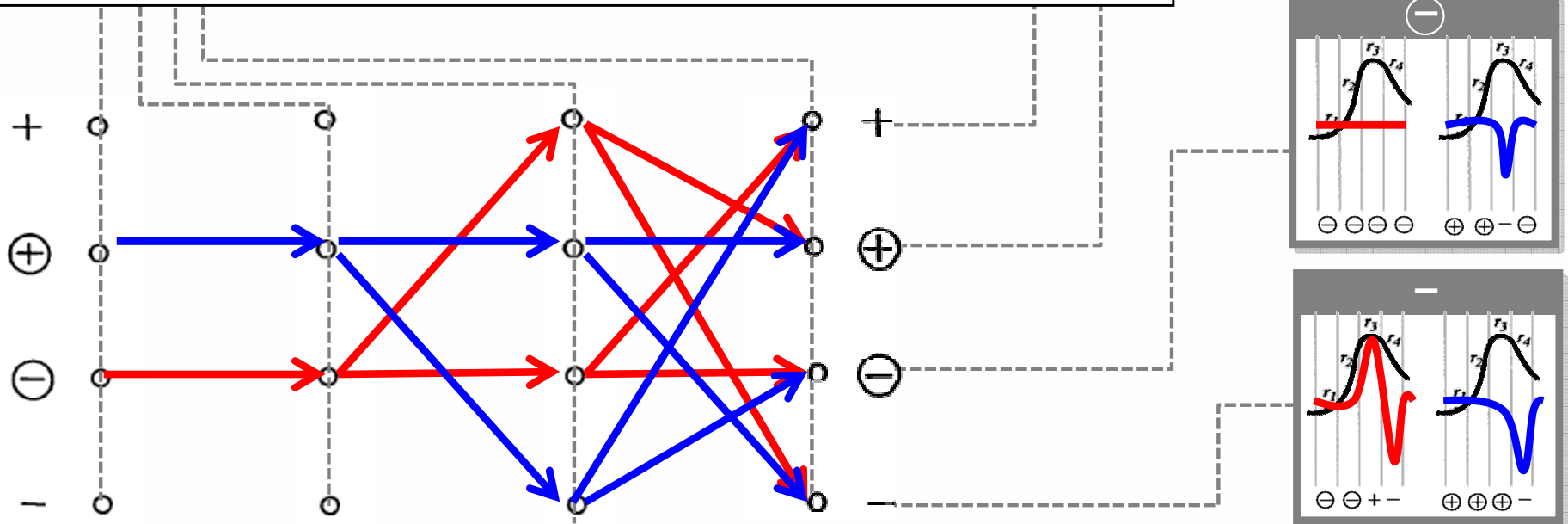
- None of these steps are in CMU’s construction

Background: Technology Tutorials

- Marvell Tutorial 31-52, CMU Tutorial 62-110



Conceived by Andrew Viterbi in 1967
as a decoding algorithm for noisy
digital communication links
*(used in cell phone signals, satellite
and deep space communication,
speech recognition, Wi-Fi and more)*



CMU's Construction Fails

- CMU claims to rely on the Fitzpatrick patent

and all possible sequences of noiseless samples. The Viterbi algorithm is an iterative algorithm for determining the ~~minimum metric path through a trellis, where the metric in this case is the squared Euclidean distance. During each clock cycle, an EPR4 Viterbi detector updates eight state metrics and selects one survivor path for each of the eight states. The survivor path represents the minimum metric~~

CMU Brf. at 36

U.S. Patent No. 5,689,532 2:35-41
(Marvell Exh. 37)

- But CMU fails to include:

- ▶ Calculating branch metrics
 - Kavcic called this “the key component”

The key component of the Viterbi algorithm is the computation of the *branch metric*. A *branch* is defined as a

Kavcic, *The Read Channel*, Proc. IEEE, Vol. 96 No. 11, at 1765 (2008)
(Marvell Exh. 21)

- ▶ Also omits comparing metrics and retaining best path

CMU's "Viterbi-like" Arguments Fail

- CMU argues that “a ‘*Viterbi-like*’ detector does not need to calculate the branch metric for every branch.” CMU Brf. at 37
- Fails for Two Reasons:
 1. Parties agreed that “Viterbi-like” means “similar to and including the ‘Viterbi algorithm.’” [Dkt. 74]
 2. The Viterbi Algorithm calculates metrics for each branch

distributed Gaussian noise with zero mean. The Viterbi algorithm is an iterative process of keeping track of the path with the smallest accumulated metric leading to each state in the trellis. The metrics of all of the paths leading into a particular state are calculated and compared. Then, the path with the smallest metric is selected as the survivor path. In this manner all paths which can not be part of the minimum metric path through the trellis are systematically eliminated.

U.S. Patent No. 5,689,532 7:64-8:4
(Marvell Exh. 37)

Sequential decoding is a sub-optimal but computationally efficient technique for decoding trellis based codes (esp. convolutional codes) [7], [8]. This technique searches through the trellis of the encoder efficiently to produce the most probable path. The Viterbi algorithm, on the other hand, searches through all the states in the trellis, and has exponential complexity with increasing constraint lengths of the encoder. The BCJR [9] decoder generates *a posteriori* probabilities for trellis based codes, but is at least twice as complex as the Viterbi decoder.

McLaughlin, *Sequential Turbo Decoding*, 36 IEEE Trans/ Magn/ at 2179 (2000) (Marvell Exh. 40)

CMU's Construction Goes "Beyond Viterbi-like"

- CMU's construction encompasses any trellis-based algorithm
- The '180 Patent describes "beyond Viterbi-like:"

The teachings of the present invention can be extended beyond Viterbi-like detectors to apply to turbo decoders, soft-decision detectors, and detectors utilizing the Viterbi algorithm, the BCJR algorithm, the Soft-Output Viterbi Algorithm (SOVA), and other similar algorithms.

'180 Patent 14:9-13

- ▶ CMU's construction improperly covers some of these sequence detection algorithms